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GEOLOGICAL HISTORY OF THE KINKI DISTRICT, JAPAN DURING THE CAINOZOIC ERA (PRELIMINARY NOTE)

BY

Susumu MATSUSHITA

1. Introduction

For the research to prevent natural disasters of a district such as landslides and earthquakes, it is necessary to know the geology of this distrct, and it is useful to understand the physical growth or geological history of the district. In this sense the writer intends to try to write the Cainozoic* geological history of the Kinki district in the central part of which our city Kyoto is situated.

The Kinki district is located in a western central part of Japan, its area and population being about 33,000 km^2 and 15,500,000 respectively. The Kinki district is one of the most densely populated districts of Japan. In this district there are three large cities of over one million inhabitants, i.e. Kyoto (1,220,000), Osaka (3,012,000) and Kobe (1,114,000).

The Kinki district occupies the western central part of Honshu, extending between 35°45′ N and 33°27′ N and between 134°12′ E and 136°55′ E. The Kinki faces the Japan Sea on the north side and the Pacific on the south.

Since the end of the World War II the resarch of the Cainozoic of the Kinki district has been very actively carried out by many geologists, new scientific data having much accumulated. Using these data, the writer is now trying to synthetize the Cainozoic history of the district. The writer is indebted to the authors of the papers listed at the end of this paper and is especially much grateful to Prof. K. Huzita who has permitted me to reproduce some of the figures of his paper.

2. Geomorphology and Geology

a. Geomorphology

Situated between the narrow Chûgoku district on the west and the wide Chûbu district on the east, the Kinki district is intermediate in width between the former

* The Cainozoic (Cenozoic) which has lasted for 70,000,000 years is the youngest era of the geological age.

two districts. The western half of the Kinki is narrow (85-100 km wide), while the eastern half is more than twice (210 km wide) as wide as the former. In the eastern half the 120 km long Kii peninsula projects into the Pacific Ocean.

Though the Kinki district is mountainous, there is no peak higher than 2,000 m. Several intermontane basins and coastal plains are involved in the district, but no plain has a width over 40 km.

The Kinki is divided into the Kii mountainland, the Central lowland and the Northwest mountainland (Fig. 1). The boundary between the former two coincides with the Median tectonic line, while the border line between the Central lowland and the Northwest mountainland starts from Lake Mikata in Fukui Prefecture, running through the valleys of River Ado and R. Takano and passing Kyoto, reaches Akashi. The Central lowland coincides with the Kinki triangle of K. Huzita (1962).

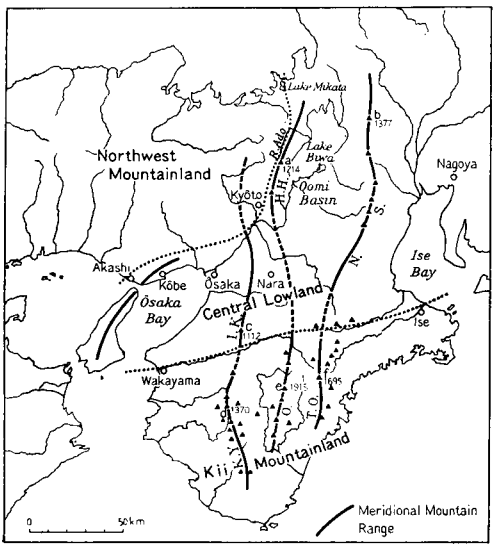


Fig. 1 Geomorphological map of the Kinki district.

The Kii mountainland is a folded one, the axis of folding running in the east and west, and is traversed by three deep valleys of Totsu, Kitayama and the upper reach of Yoshino and also by three meridional mountain ranges; i.e. the Kii-Yamato, the Oomine and the Takami-Oodaigahara ranges.

The Kii mountainland has shorelines of emergence in the south part and that of submergence in the north (exactly speaking the northeast shoreline of the mountainland is that of emergence followed by submergence).

The Central lowland is characterized by the alternation of meridional zones of elevation (mountain or hill ranges) and those of depression (basins), thus the Osaka plain, Ikoma-Kongô range (highest peak 1,112 m), Kyoto-Nara basin, Hira-Hiei range (1,214 m), Oomi (Lake Biwa) -Iga basin, Suzuka-Nunobiki range (1,377 m) are arranged from the west to the east. Lake Biwa is the largest fresh water lake in Japan (area: 675 km^2, height of lake level above sea level: 86.3 m, depth: 104 m).

It is worthy of notice that the Ikoma-Kongô, the Hira-Hiei, and the Suzuka-

Nunobiki ranges seem to continue southward respectively to the Kii-Yamato, the Oomine and the Takami-Oodaigahara ranges in the Kii mountainland (see Fig. 1).

The Northwest mountainland is for the most part mountainous with several small basins therein. It is high in the east part (highest peak 966 m), as well as in the west part (highest peak 1,510 m), while it is low in the middle and southwest. As to the shoreline on the Seto inland sea, that to the west of Murotsu is of submergence, whereas the remainder is of emergence. The shoreline on the Japan Sea is largely of submergence with an exception the Yosa (Tango) peninsula which is an upheaved block.

b. Geology

Southwest Japan, to which the Kinki district belongs, is divided by the Median tectonic line running parallel with the Japan island arc into the Outer zone and Inner zone. The Median line passes in the Kinki the immediate south of the Awaji island, the immediate north of the city of Wakayama, the Takami pass and the immediate north of the city of Ise (formerly called Ujiyamada), thus traversing in nearly east and west direction the Kii peninsula.

The Outer zone is characterized by the zonal arrangement of various geological formations of different ages and by the almost absence of granitic rocks, whereas in the Inner zone the granite batholith is fairly extensively exposed and volcanic and pyroclastic rocks chiefly of Cretaceous and Tertiary periods are as well extensively distributed, in the Inner zone the area of these rocks being wider than that of the sedimentary formations.

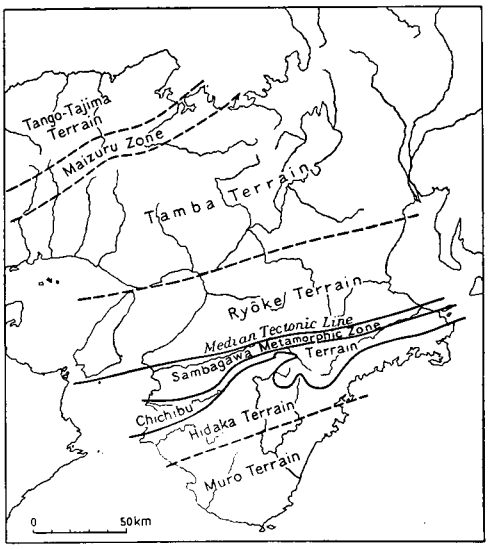


Fig. 2 Tectonic division of the Kinki district.

The Outer zone is composed of the following four terrains arranged zonally from the north to the south, i.e. (1) the Sambagawa metamorphic terrain consisting of dynamo-thermally metamorphosed Palaeozoic, (2) the Chichibu terrain chiefly composed of Palaeozoic and fossiliferous Mesozoic, (3) the Hidaka terrain consisting of undivided Mesozoic with little fossils and (4) the Muro terrain mostly composed of Tertiary sedimentary formations overlain by a series of Tertiary acid volcanic rocks (Fig. 2). The boundaries among these terrains are generally

believed to be thrusts dipping north.

Though in the Inner zone the zonal arrangement is not so distinct as in the Outer zone, the former may be divided from north to south into (1) the Tango-Tajima terrain composed of the Neogene volcanic and sedimentary series, (2) the Maizuru zone consisting of Permian and Triassic marine formations and Yakuno intrusive rocks, (3) the Tamba terrain composed of upper Palaeozoic together with Cretaceous granite, Cretaceous acid volcanic series and the Cretaceous nonmarine sediments, and (4) the Ryôke terrain consisting chiefly of Ryôke metamorphic rocks and granites. The Cainozoic formations are mainly or exclusively distributed in the Tango-Tajima, Ryôke, Muro terrains and the southern part of the Tamba terrain.

3. Stratigraphy and Structure of the Cainozoic

Palaeogene

The Palaeogene formations are limited in the Kinki district to the Outer zone. They are the Muro group and the Nakaoku formation, both marine. The former composes together with the Miocene Kumano and Tanabe groups the Muro terrain, while the Nakaoku formation occurs in the Chichibu terrain in several small areas, resting unconformably on the Upper Palaeozoic; the clastic dykes which are presumed to have been formed at the same time as the Nakaoku formation extends from the Chichibu terrain to the Hidaka terrain. Fossils from the Muro are few; they are foraminifer, mollusc and algae.

Muro group (Muro series, T. Suzuki, 1938)

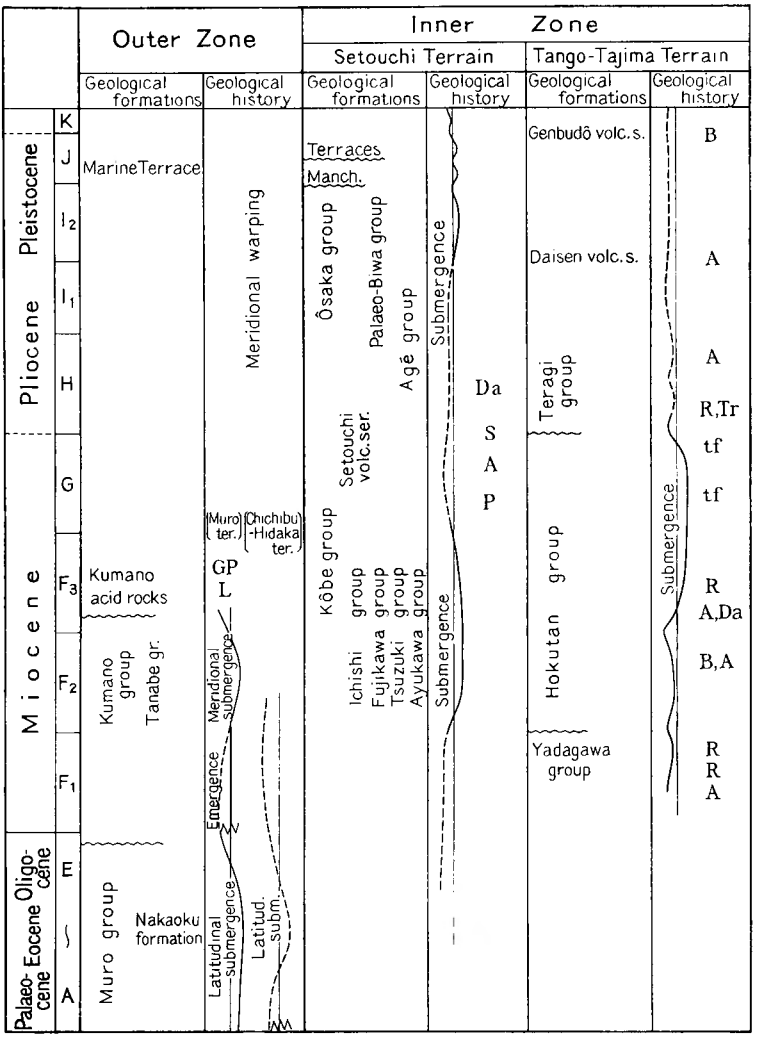
The Muro group is a thick (perhaps thousands metres thick) group of formations composed of sandstone and shale, in some cases associated with conglomerate. It is also called the Higashi-Muro group (M. Murayama, 1954) or Kinan group (T. Tanai and A. Mizuno, 1954). The age of the Muro group is assigned to Eocene or Oligocene or both of them.

According to the unpublished results of the Research association for the Muro group, the structure of the Muro group is not simple. It is considerably folded roughly in the east and west direction, in some cases overturned southward.

Nakaoku Formation (I. Shiida, 1954)

This formation with a thickness of only several tens of metres consists of conglomerate and coarse-grained sandstone. The age of the Nakaoku is considered by Shiida to be Eocene or Oligocene, on account of foraminifer *Cyclamina pacifica* and *C. tani* he found in the formation. The Nakaoku seems to have not been disturbed by crustal movements.

Table Showing the Cainozoic History of the Kinki District



A : Andesite, B : Basalt, Da : Dacite, P : Pitchstone, R : Rhyolite, S : Sanukite.
Fujikawa group is to be read as Fujiwara group.

Neogene

Late Cainozoic formations including volcanic ones of southwest Japan are distributed in three zones as described by K. Huzita (1962), i.e. the inner zone along the Japan sea, the median zone and the outer zone along the Pacific ocean. N. Ikebe (1956, 1957) proposed the names as sedimentary provinces for these three zones, namely the Hokuriku-San'in, the Setouti and the Nankai provinces.

In this paper the names Tango-Tajima terrain, the Setouchi and the Muro will be used.

Muro Terrain

Resting unconformably on the Palaeogene Muro group, the Tanabe and the Kumano groups are distributed on the west side and on the southeast side respectively of the Kii peninsula.

The Tanabe and the Kumano groups are both middle Miocene marine formations provided with marine molluscan fossils. The Tanabe group (T. Takeyama, 1930) including Kanayama group is a thick (over 1,000–2000 m) formation of conglomerate, sandstone and shale dipping seaward with an angle of 10°–40° and forming an arc with the centre in the sea.

The Kumano group (T. Tanai and A. Mizuno 1954) which comprises the Miyai group and Shimosato series is a thick group (2,000–4,000 m) of formations with thin anthracite seams in the upper part. The Kumano group is covered by the Kumano acid rocks (liparite and granite-porphyry) and forms a basin structure.

There are coastal terraces, several tens of metres high in the south and east parts of the Kii peninsula. The upper part of the terrace is composed of younger Pleistocene marine sediments with molluscan and foraminiferal fossils.

Setouchi Terrain

The late Cainozoic sediments in the Setouchi terrain have been fully discussed by K. Huzita (1962). They are classified into the following three series, i.e. 1) the First Setouchi series (middle Miocene, mostly marine), 2) Setouchi volcanic series (upper Miocene) and 3) the Second Setouchi Series (Plio-Pleistocene, mostly non-marine). The First Setouchi in the Kinki district is composed of Ichishi (Itisi) group (<650 m), Yamakasu group, Fujiwara (Huziwara) group, Ayukawa group, Awa group, Tsuzuki group, all marine and Kôbe group (500 m), almost fresh-water. Their distribution is shown in Fig. 3.

The Setouchi volcanic series is represented by the Nijô (Nizyô) group which is composed of two series of various kinds of lavas and their associated pyroclastic sediments. The Nijô group occupies a small area on the boundary line between the two prefectures of Osaka and Nara.

The Second Setouchi series compries the loose sediments made of gravel, sand and clay, and is distributed in several meridional basins in the Central lowland mentioned above. The series is mostly non-marine. The Agé, the Palaeo-Biwa and the Osaka groups belong to this series. The former two are wholly lacustrine, while the upper half of the latter is marine. The marine upper Osaka group invades into Kyoto basin.

Tango-Tajima Terrain

There are distributed in this terrain thick Neogene formations composed of

Fig. 3a Distribution of the First Setouti Series and its corresponding strata in Southwest Japan. 1: Mizunami group. 2: Ayukawa group. 3: Tuzuki group. 4: Tomikusa group. 5. Sidara group. 6: Tita group. 7: Itisi group. 8. Yamakasu group. 9: Huziwara group. 10: Kôbe group. 11: Sikai, Obié, Namigata beds. 12: Bihoku group. 13: Sinzi group. 14: Hokutan group. 15: Yatuo group. 16: Kurami and Saigô groups. 17: Kumano group. 18: Tanabe group. (After K. Huzita).

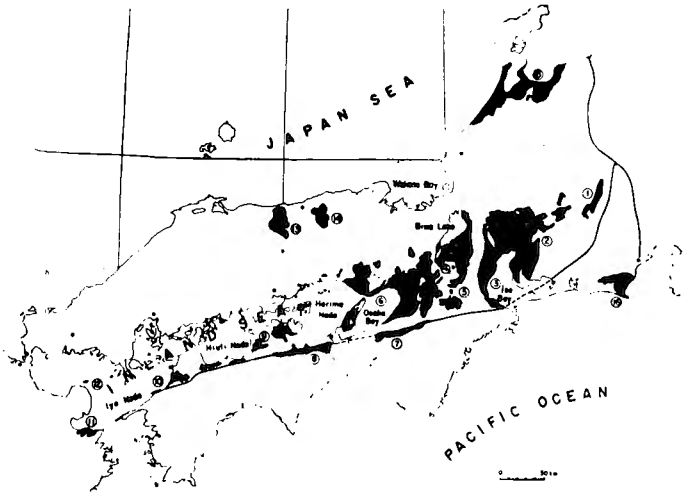


Fig. 3b Distribution of the Second Setouti Series and its corresponding strata in Southwest Japan. 1: Ina group. 2: Seto group. 3: Agé group. 4: Paleo-Biwa group. 5: Soni group (Murô). 6: Osaka group. 7: Ooyodo and Syôbudani formations. 8: Strata along the Yosino River. 9: Mitoyo group. 10: Guntyû formation. 11: Ooita group. 12: Himesima formation. 13: Ningyô-tôge formatiom. 14: Teragi group. 15: Omma formation. (After K. Huzita).

sediments and various lavas associated with their pyroclasts. The Neogene in the northern Tajima (called Hokutan) area has been well studied by K. Wadatsumi and T. Matsumoto (1958).

4. Cainozoic History of the Kinki District

Palaeogene (see Fig. 4)

As mentioned above, the Palaeogene Nakaoku formation rests unconformably on the upper Palaeozoic in the Chichibu terrain and the clastic dykes presumed to have been formed at the same time as the Nakaoku extend from the Chichibu terrain to the Hidaka terrain. Accordingly the folding and thrusting (both in the latitudinal trend) and further denudanion in the Chichibu and Hidaka terrains must have taken place before the deposition of the Nakaoku which is Eocene or Oligocen in age, and after the deposition of the Mesozoic formations (Triassic-Cretaceous) composing the Hidaka terrain, in other words during the period from late Cretaceous to early Eocene. According to I. Shiida, the clastic dykes accompanying the Nakaoku formation were formed along the meridional anticlinal axis, so that this folding may be said a forerunner of the meridional folding since the Miocene. In the Palaeogene time the Kinki district except the Chichibu, Hidaka and Muro terrains was a dry land.

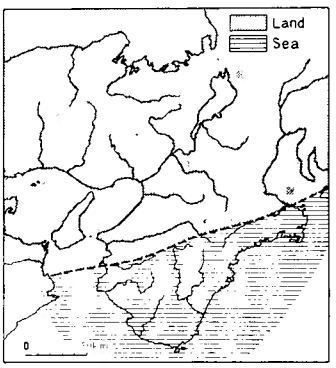


Fig. 4 Palaeogeography of the Kinki district in the Palaeogene time.

Toward the boundary between the Hidaka terrain and Muro terrain the degree of the orogenic movements and the amount of denudation decreased. In the Muro terrain and the southernmost part of the Hidaka terrain, the marine flysch-type sedimentation took place during the larger part of the Palaeogene time.

In the Eocene or Oligocene the sea transgressed from the Shimanto geosyncline to the Hidaka and Chichibu terrains and the Nakaoku formation was deposited there. The surface of its basement was fairly uneven.

At the close of the Oligocene epoch the Muro group which was deposited in the Muro terrain was subjected to orogenic movements (the so-called Oyashima or Shimanto orogeny), being folded and thrust (both in the latitudinal trend).

The Inner zone of the Kinki district is considered to have been a dry land without lake basins, since there are no Palaeogene marine and lacustrine sediments in the Inner zone.

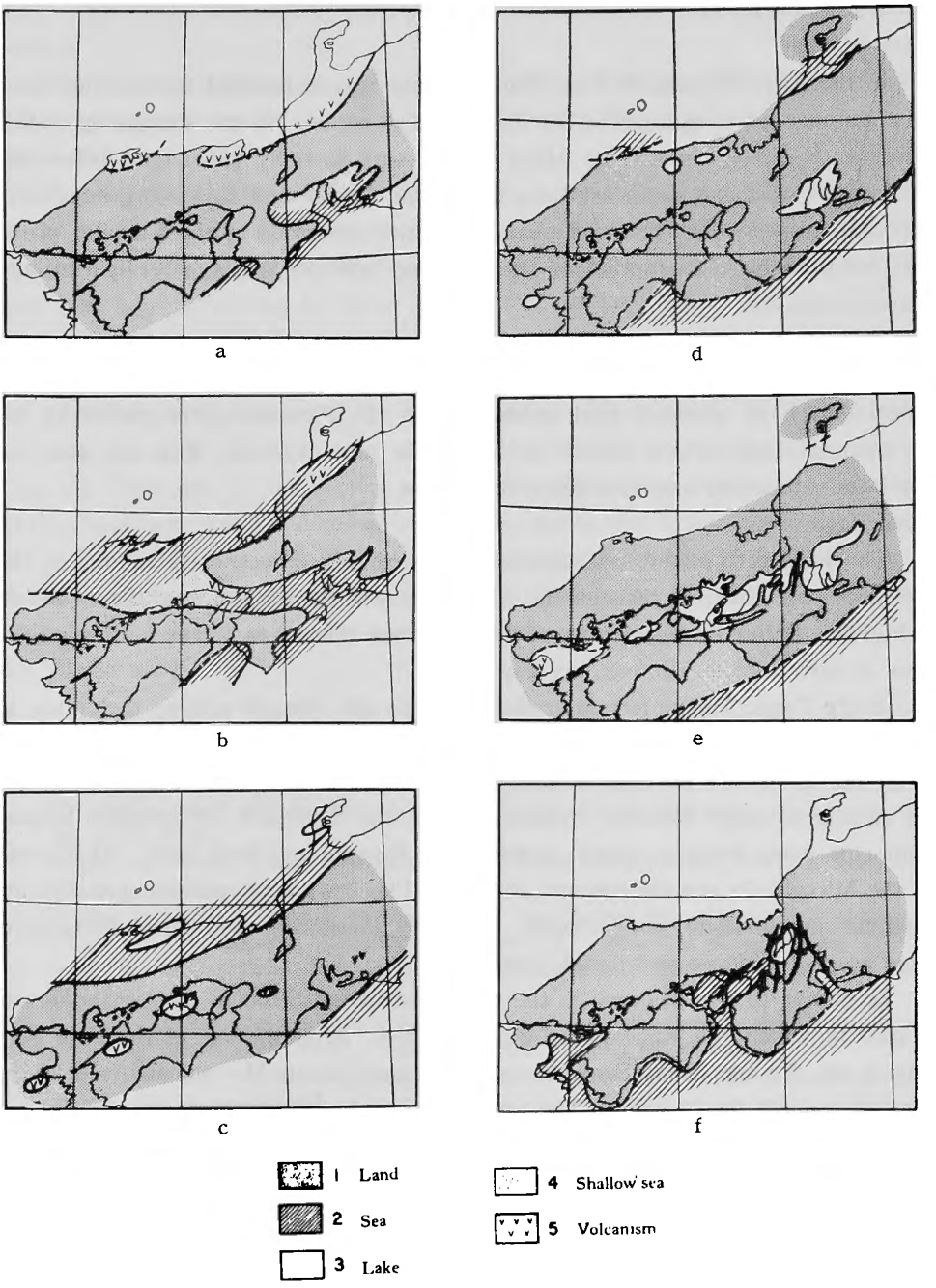


Fig. 5 Palaeogeography of southwest Japan in the late Cainozoic. (After K. Huzita). a : F_2 age (middle Miocene), b : F_3 age (middle Miocene), c : G age (upper Miocene), d : H age (Pliocene), e : I_1 age (Plio-Pleistocene), f : I_2 age (Pleistocene).

Neogene (see Fig. 5)

Outer Zone

In the early Miocene (F_1) the Muro terrain was denudated and at the same time commenced to upwarp in the meridional direction. In the succeeding middle Miocene (F_2–F_3) the upwarped Muro terrain was partially submerged below sea level on its west and southeast sides where the Tanabe and Kumano groups were deposited respectively. In the Kumano area, the deposition of the Kumano group was followed by the eruption of the Kumano acid rocks, namely liparite and granite-porphyry.

Though there is no evidence directly indicating the earth history in the Pliocene, the Muro terrain including the Miocene sediments and volcanic area is inferred to have persisted land condition. In the Pleistocene the outline of the Kii mountainland became similar to that of the present. Since then the shoreline has been submerged and emerged a few times.

Inner Zone

The First Seto inland sea appeared in the middle Miocene, extending in the east and west direction through the Median zone of the Kinki district, i.e. as shown in Fig. 5b. Before the appearance of the inland sea, there was a lake in the Suzuka area in early middle Miocene (see Fig. 5 a).

In the Tango-Tajima terrain on the Japan sea side volcanic activity took place in early Miocene, and andesitic and rhyolitic lavas were erupted. After a short disturbance, in middle Miocene a lake appeared and then it became marine. Thus the middle to upper Miocene Hokutan group was deposited. It includes besides sediments many lavas of basalt, andesite and rhyolite and their tuffs. At the end of the Miocene the sea disappeared, and in the Pliocene a lake appeared and rhyolite, trachyte and andesite were erupted. In early Pleistocene and latest Pleistocene were erupted andesite and basalt respectively.

In middle to late Miocene in the northwest of the Setouchi terrain there was a lake in which the Kôbe group was deposited. After the age of the First Seto inland sea, the age of the Setouchi volcanism came in late Miocene and might have continued untill the Pliocene. The area of this volcanism was small.

The Pliocene and Plio-Pleistocene age was of the Second Setouchi series. At that time the Rokkô* movement of N. Ikebe (1956) took place, forming alternation of several basins and ranges of meridional trend (Suzuka trend of K. Huzita, 1962). The meridonal basins were mostly lake basins. The Ise basin first appeared, and then the Oomi-Iga basin and the Osaka basin followed. The making of the Oomi-Iga basin proceeded from south to north. The Ise and Oomi-Iga basins were lake

* So named after the Rokkô mountain range near Kobe.

ones, while the Osaka basin was at first lacustrine and afterwards changed to marine.

The Rokkô movement was a foundation-folding accompanied by thrusting. The Rokkô movement reached its culmination in middle Pleistocene.

Palaeoclimate

It is generally believed that it was warm in the Palaeogene time. In the case of the Kinki also this has been confirmed by K. Koriba and S. Miki (1939) who studied the fossil algae *Paleodictyon* and *Hydrodictyon* found in the Muro group near Tanabe. According to them, the habitat of these algae was probably the brackish water lagoons and estuaries and the climate of Japan at that time was probably a little warmer than at present.

The Pleistocene climate in the Kinki has been discussed by M. Itihara (1961), M. Itihara and Y. Takaya (1961) and S. Kokawa (1961). M. Itihara considered that the beginning of the decline of the *Metasequoia* flora showed the beginning of the Pleistocene epoch and he recognized five glacial ages in the Pleistocene history of the Osaka-Akasi area on the basis of the extinction of the *Metasequoia* flora or the appearance of the boreal flora or the unconformity. S. Kokawa found five *Menyanthes* horizons in the Pleistocene of Japan and considered that they indicated the glacial ages.

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